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EXPERIMENTING BICYCLE HANDLEBAR FOR THE EVALUATION OF MUSCLE FATIGUE, GRIP STRENGTH & OXYGEN SATUARATION PERCENTAGE ON CYCLIST'S COMFORT

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ABSTRACT

Using conventional handlebars leads to considerable discomfort and a verity of chronic muscle injuries. This necessitates a proper bicycle handlebar design to avoid the muscle injuries and thereby enhance rider comfort. The objective of this study was to investigate the effect on the rider comfort during cycling by observing muscle fatigue, grip strength and oxygen saturation percentage using EMG setup. Eighteen male and eight female volunteers participated in the study. The EMG signals were acquired bilaterally from rider's wrist, triceps and late during 20 minute of cycling on outdoor road site. Also, the myometer was attached to both hand rest position on a handlebar to acquire the grip strength data, and the pulse oxymeter was fixed to rider's first finger to acquire the heart beat and oxygen saturation percentage. From this study, it was found that when at less fatigue value, maximum grip strength, and at stable oxygen saturation percentage, maximum comfort is recorded. The study also showed that there is a significant lesser fatigue when grip strength is more.

KEYWORDS: Comfort, EMG, Grip Strength & Muscle Fatigue

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Original Article

1. INTRODUCTION

In India, the bicycle also called as, a bike of a rural people and effective equipment towards fitness of a rich people. Although bicycles are produced in dozens of countries, the top five producers are China, India, the European Union, Taiwan & Japan that are responsible for 87 % of global production. The handlebar is the most important component of any type of vehicle. However, the type of bicycle differs in the design of handlebar. By choosing the bicycle for conventional purpose, the handlebar is different; this leads to increase in the risk of chronic injuries such as musculoskeletal disorders (MSD), compression neuropathic and so on. Hence, proper bicycle handlebar design is necessary to reduce MSD and enhance comfort for riders [1, 2, 3]. Cyclists adopt a round back or flat back posture to reach the handlebars by flexing their pelvis and spline [4, 5]. By conducting a survey in western vidharbha region, it was found that in rural region, 33 % of the peoples are using bicycle as a mode of transportation. For example, the postman has to deliver a letters from home to home; the working schedule is normally 40 hours per week. This prolonged bicycling demands a very high physical capacity with high energy expenditure, which often exceeds the recommended level. The mean oxygen uptake (VO2) during 8 hours working days should not exceed 30 % of maximum capacity of oxygen uptake and subsequently develops fatigue [6].

Muscle fatigue is an important feature affecting cycling performance. It has been reported that muscle fatigue would alter the cycling motion and muscle activation pattern [7]. In western Vidarbha region, the people are used with bicycle for transportation from one place to another place, also called endurance cycling. This cycling requires prolonged flexed posture, which appears to be one of the main reasons for lower limb and lower body problems [8, 9]. Since cycling relies almost entirely on the lower body for propulsion across the terrain in a seated position, numerous cycling studies have examined mostly the lower extremity muscles [10, 11].

Bicycles are designed to meet specific needs that are usually associated with cycling efficiency safety and comfort. Each bicycle designer designs different frame sizes and dimensions for seats and handlebar reflecting the quality of their brands, and satisfying the qualities of their brands and satisfying the demands of their users. Some cyclists, who suffer from back-pain, modify their bicycle design with extra-high handlebars, so that they can sit upright with their back straight. High handlebars decrease the load on the lower cervical spine and reduce the risk of prolonged neck extension [12]

Majority of the bicycle design studies focus on race cycling and their relationship between posture and prevention of injuries caused during long periods of cycling [13]. There are fewer investigations on the relationship between the evaluation of muscle fatigue, grip strength and oxygen saturation percentage on cyclist's comfort [14].

In this study, the aim and objective is to find out the optimal position of handlebar, by considering minimum muscle fatigue with maximum hand grip strength and at stable oxygen saturation percentage

2. METHODS

2.1 Participants

In this work, 18 male and 8 female were selected to participate in this study. Their mean (SD) age was 23.7 (2.0) years, and the ages ranged from 21 to 40 years. Their mean (SD) height and weight were 172.5 (range: 168e181) cm and 66.2 (range: 60e75) kg, respectively. Table 1 shows the demographic data for 26 male and female participants. Participants who had a history of musculoskeletal injury or pain or cardiovascular problems were excluded. All participants maintained exercise habits and physical stamina, and bicycled regularly. Each participant agreed to avoid staying up late or using excessive energy during the experimental period. An extra supporting staff was present for those, with unsafe cycling behavior.

Table 1: Demographic Data for 26 Male and Female Participants

Items	Mean	Range
Age (years)	31	21-47
Stature (cm)	161.23	155.44-176.78
Body mass (kg)	63.47	51.1-97.45
Preferred handle height (cm)	95.25	88.9-101.6
Preferred handle width (cm)	44.2	39-49
Preferred handle inclination (degree)	120^0	60^0-120^0
Cycling weekly distance (km)	20	10-40
Cycling regularly (times/week)	3.1	2-7

2.2 Test Protocol

The cycling tests were performed outside on a large parking lot of Prof. Ram Meghe Institute of Technology and Research, Badnera- Amravati, Maharashtra, India College premises with no other road users interfering. The participants

were asked to perform the cycling activities in a defined way, cycling for 20 minutes at self selected comfortable velocity. The three repetitions of every test are performed and averages reading are noted down. The participants were able to retreat from the tests at any stage.

2.3 Design of Handlebar using Anthropometric Features

Fifteen anthropometric measures of bicycle riders which are found related to this work system are identified. These are height (H), Arm length (La), Fore arm length (Lf), Length of palm (Ra), Grip Length of palm (Ra/2), Total Length of Arm (Lt), Shoulder distance (Sd), Elbow angle(α), Distance between Elbow (Ld), Wrist flexion (β), Stomach Abduct (θ), Bent angle (ϕ), Grip diameter (dg), angle between the chest and Arm (ϒ) Distance between the handle arm and saddle(Lh). Human body weight (W) was also considered.

After performing the statistical analysis on anthropometric data of male and female cyclists, following features are considered for the design of bicycle handle viz. shoulder distance, distance between elbow, bent angle, grip diameter, distance between handle arm and saddle, arm length. Figure 1 shows the adjustments and geometric features of handlebar.

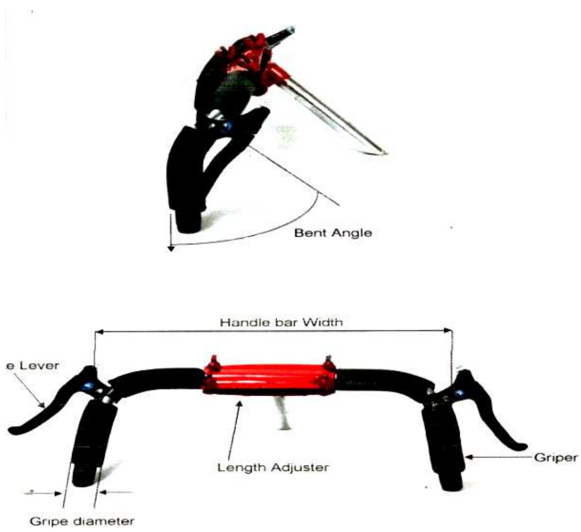

Figure 2.1: Geometric Features and Adjustments Provided to the Handlebar

2.4 Experimental Procedure

The detailed procedure of performance of the test, as per the experimental plan, prepared for this test is stated here. The test involves several subdivisions as given below.

2.4.1 Setting up of the Bicycle Parameters

The bicycle parameters as per the experimental plan were set on the adjustable handle designed and fabricated for the experimentation. The various parameters like handle height H, Handle width W, Handle Inclination angle α are set as per the design of experimentation and measuring instruments.

2.4.2Measurement of Overall Oxygen Saturation

The heart rate monitor can also measure the overall oxygen consumed by the male and female cyclist during cycling. The aim of this measurement is to find out the correlation between the muscle fatigue and the overall oxygen consumed.

2.4.3 Measurement of Muscle Fatigue

The muscle fatigue is depending on the road condition, environmental parameters, age of the rider and the anthropometric features of the rider. The 20 minute cycling time is decided excluding the setup time. Before taking the readings, it is necessary to make the subject have 20 minute test runs, so that the person gets a warm-up to stretch the muscles. The Trigno wireless foundation system is used for the muscle fatigue measurement.

2.4.4 Measurement of Environmental Parameters

The various equipment measures the environmental parameters like air speed, dry bulb temperature and relative humidity. An Anemometer with electronic display measures the air speed and the temperature. The readings of temperature and airspeed are recorded from the corresponding equipment by pressing the respective buttons on the meter. The value of the air speed is obtained in m/s, whereas the temperature is displayed in °C. All three environmental parameters are measured at the beginning, in the middle and at the end of every experiment.

2.4.5 Measurement of Grip Strength

The miyometer is utilised to measure the grip strength. In this work, the miyometer is attached to the handle grip in both the sides. This miyometer send the wireless data to the terminal (present at the end connected to the lab view software). The data from the miyometer is taken for 20 min time of left and right, at every second.

3. RESULTS AND DISCUSSIONS

In this study, seven independent parameters are identified. Viz. parameters related to anthropometry of operator (handle width, handle height, handle inclination angle), dry bulb temperature, relative humidity, air velocity and heart rate. After analyzing the effect of dry bulb temperature, relative humidity, air velocity and heart rate, it is decided to check the combined effect of independent parameters (handle width, handle height, handle inclination angle) on muscle fatigue, grip strength. For better analysis, the results are taken into 3D graph, so that the combined effects are to be analyzed. The results are shown in such a way that the effect of handle bar parameters are taken separately, and the muscle fatigue and grip strength are taken combined. The results are as follows

3.1 Effect of Handle Width on Muscle Fatigue and Grip Strength

Figure 3.1 shows the effect of handle width on muscle fatigue and grip strength. From the experimentation, it was found that the muscle fatigue is less at 440 mm handle width and at same handle width the grip strength of the rider is stable. To find which width is better from the above results, the 3D graph is plotted and it shows that at 340 mm handle width the grip strength is initially normal, but after the fatigue value is increased to 2 to 4 N, the grip strength decreases to 200- 50 N. It means, the lower the grip strength, rider is unstable and feeling most discomfort. Whereas, at 340 mm and 540 mm handle width, the muscle fatigue found to be less 0.5- 1.33 N and grip strength is pointed out 366 N. Thus, it is observed that whenever the grip strength is stable, the muscle fatigue is less and when fatigue is fewer, riders have more comfort and less distress. The figure 3.1 pointed out the mixture of grip strength data, muscle fatigue data and its effect on handle width. The lower handle width more significantly affects the performance of rider comfort. From the anthropometry of westerns, Vidharba region people have less shoulder distance and more distance between handle arm and saddle, this causes rider having more handle width to maintain distance between elbows. This result will be helpful to design the bicycle handlebar for less fatigue.

3.2 Effect of Handle Height on Muscle Fatigue and Grip Strength

Figure 3.2 shows the effect of handle height on muscle fatigue and grip strength. From the experimentation, it was found that the muscle fatigue is less at 1016 mm handle height and at same handle height; the grip strength of the rider is stable. The figure 3.2 shows that at 952 mm handle width the grip strength initially normal, but after the fatigue value is increases to 1.87 to 3.76 N the grip strength is decreases to 193- 47 N. It means, the lower the grip strength, rider is unstable and feeling most discomfort. Whereas, at 889 mm and 1016 mm handle height the muscle fatigue found to be less 0.2- 1.56 N and grip strength is pointed out 402 N. Thus, it is observed that whenever the grip strength is stable the muscle fatigue is less and when fatigue is fewer riders have more comfort and less distress. The figure 3.2 pointed out the implicit formation of grip strength data, muscle fatigue data and its effect on handle height. As lower handle width is more significantly affect the performance of rider comfort. From the anthropometry of westerns, the Vidharba region when comparing the measured data with male and female stature, it was found that male having more height than female. Thus, the results shows that female using handle height 889 mm and male using handle height 1016 mm has better grip strength and less muscle fatigue.

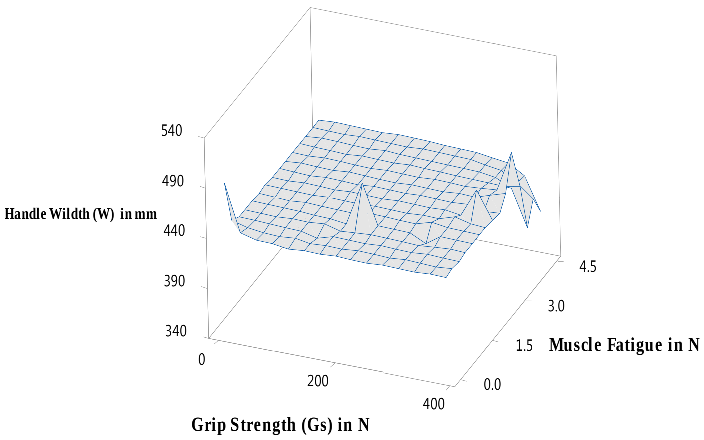

Figure 3.1: Effect of Handle Width on Muscle Fatigue and Grip Strength

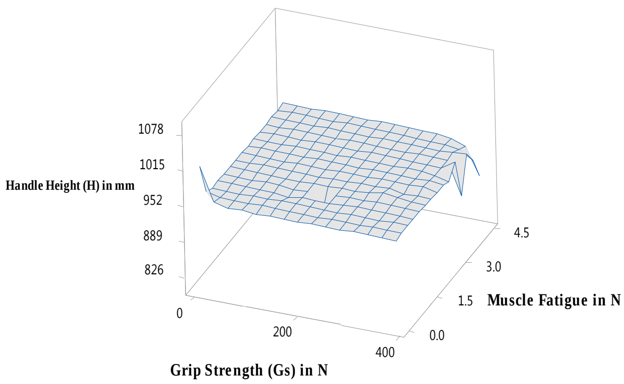

Figure 3.2: Effect of Handle Height on Muscle Fatigue and Grip Strength

3.3 Effect of Handle Inclination on Muscle Fatigue and Grip Strength

Figure 3.3 shows that effect of handle inclination angle on muscle fatigue and grip strength. From the experimentation, it was found that the muscle fatigue is less $180^{0}0$ handle inclination angles and at same inclination angle;

the grip strength of the rider is stable. The figure 3.3also shows that at 60^0 handle width the grip strength initially normal, but after the fatigue value is increases to 1.52 to 4.16 N, the grip strength decreases to 213- 57 N. It means, the lower the grip strength, rider is unstable and feeling most discomfort. Whereas, at $180^0$0handle inclination angle, the muscle fatigue found to be less 0.1- 1.16 N, and grip strength is pointed out 318 N. Thus, it is observed that whenever the grip strength is stable, the muscle fatigue is less and when fatigue is fewer, riders have more comfort and less distress, as lower handle inclination angle significantly affect the performance of rider comfort. This is because, while riding, the rider put his upper body weight on his arm and the distance between arm and saddle minimize, and the grip strength decreases and the muscle fatigue increases.

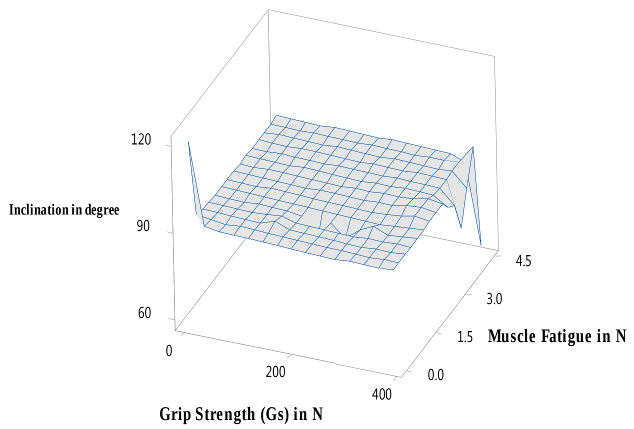

Figure 3.3: Effect of Handle Inclination Angle on Muscle Fatigue and Grip Strength

3.4 Effect of Handle Width, Handle Height and Handle Inclination Angle on Percentage Oxygen Saturation

Figure 3.4 shows the effect of handle bar parameters on percentage oxygen saturation. The figure is plotted using combination of experimental data and the anthropometric data of male and female rider. After analyzing the effect of handlebar parameters on percentage oxygen saturation, it was found that greater the oxygen saturation, the rider fills discomfort and stressful. Also, at higher rate of oxygen saturation, the grip strength is unstable. From the figure 3.4, it was found that at 440 mm handle width, 1015 mm handle height and 120^0handle inclination angle, the less oxygen saturation percentage was pointed out.

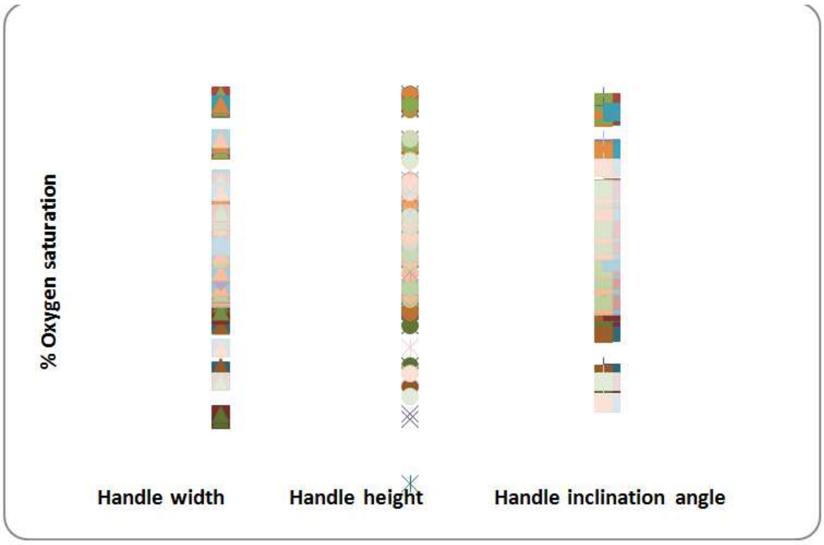

Figure 3.4: Effect of Handle Bar Parameters on % Oxygen Saturation

4. CONCLUSIONS

Anthropometric design of bicycle handle was prepared in this work, and following specifications are found to be suggestive. The average grip diameter of proposed handle is found to be 29.5 mm. The minimum & maximum handle width is found to be 340 mm and 540 mm. The minimum and maximum handle height is found to be 889 mm and 1016 mm. The minimum and maximum handle inclination angle is found to be 60 and 120degrees.

It is found that mean overall discomfort ratings for traditional and suggested position of handle were found to be 6.83 and 5.64 (male) respectively, and 7.12 and 5.81 female. It is also found that mean body part discomfort ratings for traditional and suggested position of handle were found to be 57.77 (male) and 57 (female) and 40.33 (male) and 39.87 (female), respectively. The optimal values of handle width, handle height, and handle inclination angle obtained by analysis are found to be 440 mm, 1015 mm, and 120 degree, respectively. These values correspond to minimum muscle fatigue, maximum grip strength, and stable oxygen saturation percentage. As the working conditions and environmental conditions cannot be controlled as per the experimental requirement, whether the observed response is on lower side or on the higher side, not be predicted. In future, the applicability of other techniques like ANN, Genetic Algorithm, Fuzzy logic etc. for the modeling of the phenomenon may also be tested. Also, this study can be performed considering lower body parts muscle fatigue and varying seating posture.

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REFERENCES

1. *L. Laios, J. Giannatsis, Ergonomics evaluation and redesign of children bicycles based on anthropometric data. International Journal of Applied Ergonomics 41(3),2010, 428-435.*
2. *M. Mellion, Neck and back pain in bicycling. International Journal of Clinics in Sports Medicine 13(1), 1994, 137-164.*

3. D. Mestdagh, In search of an optimum cycling posture. Applied Ergonomics29, 1998, 325-334.
4. E. Burke, High Tech Cycling (Human kinetics publishers, Champaign, Illinois.1996).
5. J. Usabiaga, R. Crespo, I. Iza, J. Aramendi, N. Terrados, J. Poza, Adaptation ofthe lumbar spine to different positions in bicycle racing. Spine 22(4)1997, 1965-1969.
6. E. Bernmark, C. Wiktorin, M. Svartengren, M. Lewne, S. berg, Bicyclemessengers: energy expenditure and exposure to air pollution. International Journal of Ergonomics 49(14), 2006,1486-1495.
7. R. So, J. Ng, G. Ng, Muscle recruitment pattern in cycling: a review. National Journal in Physical Therapy in Sport 6(2),2005,89-96.
8. M. Callaghan, Lower body problems and injury in cycling. Journal of Bodywork & Movement Therapies 9 (3),2005, 226-236.
9. C. Hausswirth, S. Argentin, F. Bieuzen, Y. Le Meur, A. Couturier, J. Brisswalter, Endurance and strength training effects on physiological and muscular parameters during prolonged cycling. International Journal of Electromyography and Kinesiology 20,2010,330-339
10. S. Aravind & S. Sridevi, Variations in Hand Grip Strength among Type-l and Type-ll Diabetics, IJPOT, Vol. 3(1), 1-8
11. D. Brown, S. Kautz, C. Dairaghi, Muscle activity patterns altered duringpedaling at different body orientations. International Journal of Biomechanics 29(2), 1996, 1349-1356.
12. R. Gregor, D. Green, J. Garhammer, An electromyographic analysis of selected muscle activity in elite competitive cyclists, In. Biomechanics VII (University Park, Baltimore, MD), 1982, pp. 537-541.
13. Kolehmainen, K. Harms-Ringdahl, H. Lanshammart, Cervical spine positions and load moments during bicycling with different handlebar positions. Clinical Biomechanics 4 (2),1989,105-110.
14. M. Berry, T. Koves, J. Benedetto, The influence of speed, grade and massduring simulated off road bicycling. International Journal of Applied Ergonomics 31(5), 2000, 531-536.
15. V. Balasubramanian, G. Swami, S. Varadhan, Quantitative evaluation of low back pain in bar benders. National Journal of Construction Management 20 (4), 2005,31-36.